California Public Fleet Heavy-Duty Vehicle and Equipment Inventory

Final Report

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2. Introduction

2.1 Project Background

In 1998, the California Air Resources Board (ARB) identified particulate matter found in diesel engine exhaust to be a Toxic Air Contaminant. This finding triggered the legislative requirements for the development of a risk management program focused on reducing exposure to diesel particulate matter (PM). An Advisory Committee comprising staff from the ARB, United States Environmental Protection Agency (EPA), State and local agencies, industry, environmental groups, and interested public was tasked with preparing a risk management guidance document and a risk reduction plan. The result of the committee's efforts were two documents entitled *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles,* and *Risk Management Guidance for the Permitting of New Stationary Diesel-Fueled Engines,* which were approved by the ARB board in September 2000.

The implementation of the risk reduction plan consists of developing and adopting regulation that defines diesel emission control programs for mobile and stationary diesel engines as well as for diesel fuel. These programs are designed to reduce emissions by setting emission standards and emission reduction technology requirements. Obtaining emission reductions from diesel engines currently in use is an essential component of ARB's plan. To that end, the agency has developed a heavy-duty diesel in-use program that assesses retrofit devices and develops strategies for their deployment. To date under this program, eight retrofit devices have been verified and a retrofit plan has been adopted for public transit buses. A retrofit plan is currently being developed for waste collection vehicles. ARB is also assessing the feasibility of diesel PM retrofit strategies for state and local government heavy-duty vehicles and off-road equipment not covered by the public transit and waste collection vehicle rules. The first step in this assessment is the development of a detailed inventory of the public fleets' diesel vehicles and equipment. This inventory will allow ARB to accurately determine the public fleets' diesel PM emission reduction potential and tailor the retrofit requirements to the fleets' characteristics. TIAX LLC (TIAX) was selected to develop this inventory of California's public fleets. This report summarizes the methodology used to collect the inventory data and presents the results of the data analysis. The following section further discusses this project's objectives, the tasks TIAX has undertaken to complete the inventory, and the organization of the report.

2.2 Project Objectives

As previously mentioned, the main objective of this project is to develop an inventory of diesel vehicles and equipment in use in California public fleets. The specific focus is on heavy-duty vehicles (gross vehicle weight rating of 8,500 lb. and higher) and large off-road equipment (50 HP and higher). The inventory must include all data necessary to assess the retrofit potential of each vehicle and piece of equipment. The inventory should also be:

- Comprehensive: The inventory completion goal is a minimum of 75% of the diesel vehicles estimated to operate in public fleets in the state
- Up to date: The inventory must represent the latest data available
- Accurate: Quality assurance and quality check procedures must ensure data integrity

Finally, the inventory must facilitate the completion of the second phase of ARB's retrofit potential analysis, the detailed engine and duty cycle study.

2.3 Project Tasks

The tasks summarized in Table 1-1 were designed to meet the project objectives described in Section 1.2. Task 1 regroups all activities necessary to define the data collection methodology and design the database. TIAX's receipt and processing of the completed surveys, including the data entry effort, are covered in Task 2. In the third

Table 2-1. Project Tasks

Task 1	**Inventory Database Requirements, Sources, and Methodology**	
	1.1	Confirm database goals and applications
	1.2	Review ARB refuse hauler HDDV database and methodology
	1.3	Define or confirm specific data item requirements
	1.4	Design mailed and electronic survey
	1.5	Define data sorting and analysis requirements
	1.6	Select database software/system
	1.7	Plan data collection methodology
Task 2	**Data Collection**	
	2.1	Extract mailing list from selected existing databases
	2.2	Mail survey
	2.3	Review and track received survey
	2.4	Enter received survey data into database
Task 3	**Database Quality Control, Refinement, and Analysis**	
	3.1	Database audits to identify inconsistencies and assess completeness
	3.2	Collect data from non-responsive fleets
	3.3	Database sorting and analysis as required to derive requested data summaries, conclusions, and recommendations
	3.4	Document database definitions, sources, and sorting instructions
Task 4	**Reporting**	
	4.1	Prepare and submit 50% completion Task 1 report and inventory database
	4.2	Prepare and submit draft Final Report including inventory database
	4.3	Prepare and submit revised Final Report including inventory database

task, TIAX audited entered data and identified the major data trends. Task 3 also includes data collection from non-responsive fleets. Task 4 consists of the project's three major deliverables: the 50% database completion report, the final report, and the public fleet inventory database. Activity summary reports sent to ARB on a monthly basis document TIAX's progress towards the completion of these tasks.

2.4 Report Organization

The information in the report is organized according to Table 1-2. The following section presents the methodology TIAX developed and implemented to compile the database. Section 3 describes the database and the data entry process. Section 4.1 presents the results of the analysis of fleet characteristics collected from the survey. Section 4.2 presents the results of the vehicle and equipment data analysis. Section 4.3 addresses potential biases and errors in the results of TIAX's analysis. The conclusion in Section 6 summarizes the study's main findings.

Table 2-2. Organization of Information Presented in this Report

Section 2.	Survey Methodology	Reviews survey audience choice, data collection activities
Section 3.	Public Fleet Database	Reviews design choices for database, data entry activities, QA/QC, data completeness
Section 4.1	Survey Results — Fleet Characteristics	Summarizes the characteristics of fleets that responded to the survey
Section 4.2	Survey Results — Vehicle and Equipment Characteristics	Summarizes the characteristics of vehicles and equipment in the database
Section 4.3	Biases and Uncertainty	Summarizes potential biases due to data collection and analysis methodology
Section 5.	Retrofit Potential	Discusses the current profile for engines eligible for retrofit and the number of engines in the database that may fit the profile
Section 6.	Conclusion	Summarizes the report findings

3. Survey Methodology

The public fleet inventory database is based on the results of a survey developed and conducted by TIAX from February 2002 to February 2003. This section describes the methodology used to create the survey and how the completed surveys were collected.

3.1 Target Audience

California public fleets include all state, county, and city government fleets. It also includes special districts such as water and irrigation district fleets. As the most efficient method to administer a detailed survey is by mail, it was necessary to develop a mailing list of the targeted fleets. ARB provided TIAX with two databases with the data necessary to accomplish this task. The Department of Motor Vehicle (DMV) database of diesel heavy-duty vehicles allowed us to first identify the vehicles that were owned by public fleets. These vehicles were isolated using the public vehicle license plate number format. The public fleet vehicles in the DMV database were then linked to the California Highway Patrol (CHP) MISTER database using the California Carrier Identification numbers. The California Carrier Identification number (Carrier ID) is issued by the CHP as part of their Biennial Inspection of Terminals (BIT) program and is unique to each fleet. The CHP database also includes a contact name and address for each Carrier ID. The names and addresses for Carrier IDs matching public fleet vehicles were extracted and compiled as a mailing list. Duplicates and incomplete data sets were eliminated. The final mailing list contained contact information for 575 fleets representing approximately 9,200 diesel heavy-duty vehicles. The mailing list with updated contact information for all responding fleets is provided in Appendix A.

A table with the estimated heavy-duty diesel on-road vehicle fleet size for each fleet was also prepared using the DMV data. The most recent version of this table is included in Appendix B. TIAX found the DMV population estimate of heavy-duty diesel on-road fleet population to be consistently lower than the actual diesel vehicle fleet population reported in the received surveys. The DMV data was therefore only used to prioritize the fleets to contact but not to verify the surveys. The DMV population data was also used to track the progress towards the 75% goal set by ARB, as it was the only population data available for fleets that did not respond to the survey.

3.2 Survey Form Preparation

TIAX based the public fleet survey form on several survey forms previously prepared by ARB, including the form for the recently completed ARB waste collection vehicle inventory survey. The public fleet inventory form consists of two sections: the fleet information form and the vehicle/equipment information. The fleet information form (see Figure 2-1 and Appendix C) requests basic information about the fleets. This includes contact information, fleet type, fleet size, and terminal and fueling location. Access to ultra-low sulfur diesel, which is required for several of the currently certified retrofit devices, is also requested.

FLEET INFORMATION FORM

Business Name:__________________________________Parent Company Name:______________________________Carrier ID#: _________

Company Address: ____City: ____

State: ______________________________ Zip: ________________________

Contact Name: _____________________________________Contact Title: ____

Tel: (_____)_________________________ Fax: (_____)________________________Email: ____

1. Are you a:

☐ Private Fleet ☐ Government Fleet ☐ Government-Contracted Fleet

2. How would you describe your business or activity sector?

☐ Trucking-Motor Carrier ☐ Trucking-Owner/Operator ☐ Agriculture
☐ Commercial ☐ Construction ☐ Industrial

3. How many locations do you operate from? ___________________
4. In which California counties do you operate? _________________
5. What is your on-road heavy-duty (8,500 lbs. GVWR and above) fleet size for all locations combined? ______________
6. What is your off-road heavy-duty (50 HP and above) fleet size for all locations combined? ________________
7. How do you typically acquire your equipment?

☐ Purchase new ☐ Purchase used ☐ Lease ☐ Rent

8. Fill out the following table for each of your fleet locations

Terminal ID #	Address	City	State	Zip Code

9. Where do you refuel your equipment? Please check all that apply.

☐ Fleet-owned Station ☐ Job-site Fueling Service (Wet-hosing) ☐ Retail/Truck Stop ☐ Other, Fill in:_______________

10. Do you currently have access to Ultra Low Sulfur Diesel fuel (< 15ppm sulfur)?

☐ Yes ☐ No

Figure 3-1. Excerpt of Fleet Information Form

Finally, the fleet is asked to specify what type of incentive would be required for compliance with retrofit requirements.

The Vehicle/Equipment Information form (see Figure 2-2 and Appendix C) requests vehicle and equipment specific information ranging from make and model to annual mileage and fuel use.

The survey was originally designed to request information pertaining to diesel on-road heavy-duty vehicles from all fleets including private fleets. Early in the project, ARB requested to limit the data collection to public fleets and to add other fuels (gasoline and alternative fuels) and off-road equipment to improve the efficiency of the data collection effort. TIAX and ARB decided not to eliminate the survey fields that allowed for a distinction between private and public fleet types so the form can be easily reused for future surveys. The survey forms were reviewed and approved by ARB in January 2002. ARB provided a cover letter explaining the purpose of the survey and TIAX's role in collecting the data. TIAX also included a cover letter providing instructions on how to complete the survey and contact information to submit the survey. The two cover letters are also provided in Appendix C.

Vehicle Type (1)	Application Type (2)	Equipment Make (3)	Equip/Veh Model (4)	Equip/Veh Model Year (5)	GVWR (6)	Engine Mfr. (7)	Engine Model (8)	Engine Model Yr. (9)	HP (10)	Disp. (11)	Fuel Type (12)	Mech/ Elect (13)	Asp. (Diesel only) (14)	Aux Eng Y/N (15)	Odo- or Hourmeter Reading (16)	Annual Fuel Use (17)	Annual Mileage or Hours (18)
Convention	Delivery	International	9400i	1993	42,000	CAT	3406C	1993	425	14.6 L	Diesel	Mech.	Turbo	N	572,000 mile	12,000 gall	60,000 mile
Rubber Tir	Construction	CAT	9506	2000	N/A	CAT	3126	2000	180	7.2 L	Diesel	Mech.	Turbo	N	580 hours	2,800 gallo	580 hours

Figure 3-2. Excerpt of Vehicle/Equipment Form

3.3 Completed Survey Collection

The survey form was sent to the fleets on the mailing list at the beginning of February 2002 and the first completed survey was received within a week. TIAX staff followed a pre-established procedure for each survey received. Each completed survey was assigned a number corresponding to the order in which it is received.

A log of received and outstanding surveys was updated each time a survey was received. Updates consisted of entering the survey number and updating the contact information provided by the fleet. A log tallying the percentage of the estimated total fleet size represented by the received survey was also updated each time a survey was received.

Each survey was reviewed for completeness. If a form was missing, the fleet was immediately contacted to request the missing form.

The data provided in the fleet information form was also entered into the public fleet database as the surveys are received (see Section 3).

Completed surveys were received either by mail or by email. If a fleet submitted a hardcopy of the survey but the document was clearly computer generated, the fleet was contacted to request an electronic copy of the survey. Electronic files typically required less time to enter than hardcopy files, especially for large fleets. Processing electronic data was expected to reduce potential data entry errors.

By mid-April 2002, TIAX had received 85 completed surveys representing approximately 10% of the estimated fleet. In order to increase the response rates, TIAX staff began contacting all fleets that had not responded to date. Phone calls were made from mid-April to the end of June 2002.

TIAX maintained a log of all calls made, which recorded the date of the call, the result of the call, and the next action item as needed. The call logs allowed us to quantify the results and assess the effectiveness of the phone call efforts. Approximately 27% of the phone calls made resulted in TIAX mailing or emailing a new copy of the survey to the fleet. This represented nearly half of all calls in which personal contact was made with a fleet representative. 38% of phone calls ended with voice mail or messages left with administrative assistants. Overall, 53% of the contact names or numbers for the non-respondent fleets needed to be corrected. This figure is a slight underestimate since many voice mail messages that were never returned may not have been directed to the correct contact person. The large amount of inaccurate contact information is believed to be the main reason for the low response rate to the initial mailing. A large portion of the contacts listed were elected official (e.g., mayors) who were no longer occupying their functions.

Fourteen fleets (3% of the fleets contacted) declined to respond to the survey. Most of these fleets cited lack of staff and time as the main reason they would not complete the survey. At least two fleets preferred not sharing fleet information with ARB because they did not want to facilitate the development of regulations affecting their fleets.

In July 2002, the TIAX staff phone calls focused on the twenty largest fleets that had not responded to date. By the end of July 2002, 170 surveys representing close to 50% of the estimated diesel vehicle population had been received and entered in the database. These surveys included 7 of the 20 largest fleets targeted in July 2002. The data collection efforts were temporarily put on hold as staff focused on completion of the 50% completion database and the associated report.

Starting in October 2002, TIAX targeted the 31 fleets whose surveys were required to meet the 75% completion goal. Each fleet was called at least two to three times to discuss the completion of the survey. TIAX also offered to provide staff to these fleets to assist with compiling their survey response. Only one fleet, the California Department of Transportation (Caltrans) accepted TIAX's offer. Caltrans had previously submitted a database of its diesel vehicles and equipment, which was included in the 50% completion database. However, many of the requested fields were missing from Caltrans' data. TIAX staff spent one week at the Caltrans Equipment Headquarters in Sacramento reviewing purchase orders to finding missing vehicle and engine specifications. Caltrans was not able to provide usage information for their vehicles and equipment. In addition to completing the diesel vehicle and equipment records, TIAX obtained records for Caltrans' gasoline and alternative fuel vehicles.

By mid-December, three additional targeted fleets had completed their survey and three had refused to respond. At ARB's request TIAX provided ARB staff with upper management contact information for each targeted fleet that had not responded to date. ARB's Mobile Source Control Division Chief Robert Cross contacted these fleets in December and January in a final attempt to convince them to complete the survey. In February 2003, TIAX received the completed survey for the County of Los Angeles, one of the largest fleets in the state. As ARB did not expect any additional surveys would be received, the database was finalized in February 2003. The final database contains data for 178 fleets representing approximately 57% of our DMV estimated heavy-duty diesel on-road population.

The following sections describe the database and data entry process.

4. Public Fleet Database

4.1 Database Design

The Microsoft Access 2000 database was designed to facilitate the entry and analysis of the collected survey data. Similar to the survey form, it consists of the two tables for fleet and vehicle/equipment information. The Fleet Information Table compiles the data from the fleet information form including the survey number. The Vehicle and Equipment Data Table contains the vehicle and off-road equipment specific information. A survey number field in the Vehicle and Equipment Data Table links each record to the Fleet Information Table. For simplicity, on-road vehicles will be referred to as vehicles and off-road equipment as equipment in this report.

Each field in the survey form corresponds to one or more fields in the database. The database fields contain text, numbers, or check boxes for yes/no data. Additional fields were incorporated to facilitate the data analysis process. For example, a vehicle/equipment category field was created to provide a standardized vehicle and equipment type for each record. Also in the vehicle data table, a check box is used to identify the off-road equipment. Tables 3-1 and 3-2 provide a description of each table's field content and format. As the survey was originally designed for all fleets including private fleets, certain database fields allow the flexibility of entering information for non-public fleets. For example the Fleet Type and Business Sector fields in the Fleet Information Table help distinguish public and private fleets.

4.2 Data Entry Process

After a survey was received and logged as described in Section 2, the data entry process began. The fleet information form was entered in the Fleet Information Table. The survey number is the primary key for the fleet record.

The vehicle and equipment information data entry process depends on the format in which it was received. For hardcopy surveys, the data was entered manually by a data entry specialist. The manual data entry was usually performed in batches to improve its efficiency. For electronic surveys, the data was typically converted from Microsoft Word or Microsoft Excel to Microsoft Access and imported into the database. The conversion process depended on the format and the completeness of the electronic data.

Table 4-1. Fleet Information Table Fields

Field Name	Content	Format
Survey Number	Unique survey identification number	Number
Business Name	Fleet name	Text
Parent Comp Name	Parent organization name	Text
Carrier ID	California Carrier Identification number	Number
Company Address	Street/Mailing address	Text
Company City	Address city	Text
Company State	Address state	Text
Company Zip	Address zip code	Number
Contact Name	Fleet contact name	Text
Contact Title	Fleet contact title	Text
Contact Tel Number	Fleet contact telephone number	Text
Contact Fax	Fleet contact fax number	Text
Contact email	Fleet contact email address	Text
Fleet Type	Private, Government, Government-Contracted	Text
Business Sector	Trucking-Motor Carrier,Trucking-Owner/Operator, Agriculture, Construction, Commercial,Industrial,City Fleet,Other,Municipality	Text
Number of Locations	Number of locations/terminals from which the fleet vehicles operate	Text
California Counties	California counties the fleet vehicles operate in	Text
On-Road Vehicles	Number of on-road vehicles in the fleet	Number
Off-Road Equipment	Number of off-road vehicles in the fleet	Number
Typically Acquire	Purchase New, Purchase Used, Purchase New/Used, Lease, Rent	Text
Fleet-owned Station	Fueling location	Yes/No Check Box
Job-site Fueling Service	Fueling location	Yes/No Check Box
Retail/Truck Stop	Fueling location	Yes/No Check Box
Other	Fueling location	Yes/No Check Box
Other type	Specify other fueling location	Text
Ultra Low Sulfur Diesel	Availability of Ultra Low Sulfur Diesel	Yes/No Check Box
Only within California	Percent of mileage/hours operated in California	Percentage
Also outside California	Percent of mileage/hours operated outside of California	Percentage
Green Image	Incentive choice	Yes/No Check Box
Government Grants	Incentive choice	Yes/No Check Box
Tax Incentives	Incentive choice	Yes/No Check Box
Other incentives	Incentive choice	Yes/No Check Box
Other incentive type	Specify other incentive choice	Text

Table 4-2. Vehicle and Equipment Data Table Fields

Field Name	Content	Format
Survey No	Unique survey identification number linking record to Fleet Information Table	Number
Vehicle Type (1)	Vehicle description provided by fleet	Text
Vehicle Category	Vehicle description determined by TIAX	Text
Off-road?	Off-road equipment marker	Yes/No Check Box
Application Type (2)	Application description provided by fleet	Text
Application Category	Application description provided by TIAX	Text
Equip/Veh Make (3)	Equipment/vehicle make name	Text
Equip/Veh Model (4)	Equipment/vehicle model name	Text
Equip/Veh Model Year (5)	Equipment/vehicle model year	Number
GVWR (6)	Equipment/vehicle gross vehicle weight rating	Number
Engine Mfr (7)	Engine manufacturer name	Text
Engine Model (8)	Engine model name	Text
Engine Model Yr (9)	Engine model year	Number
HP (10)	Engine horsepower	Number
Disp (11)	Engine displacement in liter	Number
Fuel Type (12)	Diesel, Gasoline, CNG, LNG, Propane, Electricity	Text
Mech/ Elect (13)	Engine control type (mechanical or electronic)	Text
Turbo (14)	Diesel engine turbocharge marker	Yes/No Check Box
Aux Eng Yes/No (15)	Auxiliary engine marker	Yes/No Check Box
Odo- or Hourmeter Reading (16)	Odometer or hourmeter current reading	Number
Hours	Hour data marker	Yes/No Check Box
Annual Fuel Use (17)	Annual fuel use in gallons	Number
Annual Mileage or Hours (18)	Annual usage in miles or hours	Number
Year of last Rebuild (19)	Year of last engine rebuild	Number
License Plate Number (20)	License plate number	Text

4.3 Data Quality Assurance and Quality Check Procedures

Data quality assurance and quality check (QA/QC) procedures were implemented throughout the data entry process.

Upon receipt, a duplicate hardcopy was made of all surveys received and it was stored separately to maintain a full record of surveys received. These hardcopies included printouts of electronically received surveys. As the data was entered, spelling and typographic errors were corrected. Abbreviations were spelled out to maintain consistency in the data. For example, “Chevy” was entered as “Chevrolet”. Engine displacements provided in cubic inches were converted to liters.

Records for vehicles and equipment that did not meet the criteria of the survey were deleted or not entered. This included vehicles under 8,500 lb., equipment under 50 HP, urban transit buses, refuse collection vehicles, and emergency vehicles (fire trucks and ambulances).

The data entry staff also checked for consistency between the records for each survey. For example, the engine characteristics (HP, displacement) among vehicles of the same make and model were compared. The staff also made sure vehicle/equipment age and lifetime mileage or lifetime hours were consistent within the fleet. A data field that was very inconsistent with the fleet’s trend was deleted in order not to affect the overall trends. Entire records were not deleted for data inconsistency, only the field of concern.

The number of records was compared to the fleet’s entry in the survey’s Fleet Information Table on number of off-road and on-road vehicles. As the definition of off-road varies from fleet to fleet, all totals were adjusted to reflect common definition based on vehicle and equipment type and use. Large sweepers, for example, were considered on-road vehicles.

During the manual data entry, staff highlighted the data that could not be clearly read and/or understood. This highlighted data was reviewed by the data verification staff, and if a value could be determined, it was entered into the database.

Data entry staff was also responsible for assigning standard vehicle and application categories based on the vehicle and application type provided in the survey. Many survey respondents provided very detailed vehicle descriptions that needed to be standardized to be able to sort and analyze. For example, the vehicle type “Dump Truck, 2.5 TON” was assigned a “Dump Truck” vehicle category. Once data entry was completed, the data entry staff initialed and dated the hardcopy of each survey he or she entered.

After the data was entered another set of QA/QC procedures was implemented. A person other than the data entry staff verified the data entered for each survey. Data verification consisted in comparing the survey (hardcopy or electronic file) to the data entered in the database, correcting any errors and recorded omissions. The data verification staff also made sure that all the records corresponded to the survey criteria. Once the data was verified, the staff initialed and dated the survey hard copy.

A final series of data QA/QC procedures were implemented before the data analysis. Several queries were performed to verify the spelling of vehicle and engine makes. Queries were also performed to make sure vehicle categories and application categories were assigned correctly.

Many of the records provided were missing equipment/vehicle types and engine information. TIAX staff took several steps to reasonably estimate missing data. For example, if a record was missing equipment/vehicle type and category but contained equipment/vehicle make and model the database was sorted to compare the record to other records with the same make and model. If no clear determination could be made on the equipment/vehicle category by comparing to other records, the make and model were searched in online equipment and vehicle sale databases such as www.truckpaper.com and www.machinerytrader.com. These websites typically provided detailed description of vehicles and equipment. Finally if the results of the vehicle/equipment website search were not conclusive, the make and model were entered into a generic internet search (e.g. ,Google). Using this search method, TIAX was able to significantly reduce the number of records without vehicle/equipment categories. A similar approach was applied to determining engine horsepower and engine displacement with much less success. Some engine displacements could be extrapolated from engine model names (e.g. Cummins 5.9, International DT466). However, each engine model is available in a range of horsepower that varies with model year[1]. Therefore record comparison did not provided any conclusive estimate on engine specifications.

4.4 Record Completeness

The following tables present the percentage of records for which data was provided by field types. Missing data for certain fields such as vehicle type, gross vehicle weight rating, and horsepower affects the level of confidence that the database only contains data meeting the survey criteria. For example, records without GVWR or horsepower information could represent vehicles below 8,500 lbs. GVWR and equipment below 50 HP. In general, records in the Fleet Information Table (Table 3-3) were relatively complete, with most fields above 90% completeness. The least reported field was the contact email address. Several fleets we contacted during the data collection process mentioned they did not have Internet access. Mailing addresses seem to remain the best method to contact most public fleets. Incentive type choice was only reported in 70% of the surveys. One potential explanation is that survey respondents, which are typically fleet managers, are not usually responsible for deciding on participation in air quality programs.

[1] Engine information could not be conclusively deduced from vehicle make and model information because manufacturers offer several engine options for most heavy-duty vehicle/equipment.

Table 4-3. Fleet Information Field Completeness

Field	Percentage of Surveys with Data
Business Name	100%
Parent Comp Name	10%
Carrier ID	100%
Company Address	100%
Company City	100%
Company State	100%
Company Zip	100%
Contact Name	100%
Contact Title	93%
Contact Tel Number	99%
Contact Fax	94%
Contact email	63%
Fleet Type	98%
Business Sector	85%
Number of Locations	93%
California Counties	99%
On-Road Vehicles	100%
Off-Road Equipment	100%
Total	100%
Typically Acquire	89%
Fueling Location	88%
Ultra low Sulfur Diesel	81%
In/Out of California Operation	100%
Incentive Type	70%

Table 3-4 provides the record completeness for the fields in the Vehicle and Equipment Data Table. The most underreported fields are annual fuel use, application type, and engine control (mechanical/electronic). Record completeness was not estimated for three "Yes/No" type fields because it was not possible to distinguish between records without data and records with "No" as an input. Overall, vehicle /equipment data were better reported than engine data. This is mainly due to the fact that many fleets do not keep engine data in their fleet records. Several survey respondents reported to TIAX staff that they had to physically inspect each vehicle and piece of equipment in their fleet to collect engine data, significantly increasing the time and effort required to complete the survey.

Table 4-4. Vehicle and Equipment Data Table Completeness

Field	Percentage of Surveys with Data
Vehicle Type (1)	99%
Vehicle Category	100%
Off-road	100%
Application Type (2)	36%
Application Category	29%
Equipment Make (3)	98%
Equip/Veh Model (4)	96%
Equip/Veh Model Year (5)	94%
GVWR (6)	72%
Engine Mfr (7)	60%
Engine Model (8)	47%
Engine Model Yr (9)	37%
HP (10)	70%
Disp (11)	54%
Fuel Type (12)	98%
Mech/ Elect (13)	31%
Turbo (14)	N/A
Aux Eng Yes/No (15)	N/A
Odo- or Hourmeter Reading (16)	54%
Annual Fuel Use (17)	25%
Annual Mileage or Hours (18)	35%
Year of last Rebuild (19)	N/A
License Plate Number (20)	45%

5. Survey Results

The following sections provide the results of the analysis of the public fleet inventory database. Section 4.1 focuses on fleet characteristics of the 178 fleets in the database. The characteristics of the 18,873 vehicles and 5,560 pieces of equipment are discussed in Section 4.2. The biases and potential errors in the analyses are assessed in Section 4.3.

5.1 Fleet Characteristics

The data compiled in the Fleet Information Table were analyzed to develop a profile of public fleets operating in California. TIAX also evaluated how representative the responding fleets are of the entire public fleet. The next sections explore the surveyed fleets' activity sector, size, and geographic distribution.

5.1.1 Activity Sector

As shown in Table 4-1, most of the surveys received were from city and county fleets. Water and irrigation districts are the second most represented group in the database. This distribution is similar to the distribution of fleet types for all fleets that were sent a survey, which is presented in the last column of Table 4-1.

Table 5-1. Activity Sector Distribution

Fleet Type	Received Survey	Distribution of Survey Respondents	Distribution of Sent Surveys
City	77	43%	51%
County	30	17%	12%
Water District	31	17%	14%
Irrigation District	12	7%	6%
Transit	10	6%	5%
University	6	3%	4%
Utility District	6	3%	2%
State	4	2%	3%
Airport	1	1%	1%
Misc.	0	0%	1%
School District	1	1%	1%
Federal	0	0%	<1%
Port	0	0%	<1%

Table 4-2 presents the response rate by fleet type. Overall, 31% of the fleets that were sent a survey responded. The response rate is the highest for utility districts and county fleets. TIAX received no responses from federal, port, and other miscellaneous public fleets (i.e., tribal councils and agricultural associations).

Table 5-2. Response Rate by Fleet Type

Fleet Type	Survey Respondents	Surveys Sent	Response Rate
Utility District	6	12	50%
County	30	70	43%
Water District	31	82	38%
Transit	10	28	36%
Irrigation District	12	34	35%
Airport	1	3	33%
City	77	293	26%
School District	1	4	25%
University	6	25	24%
State	4	17	24%
Federal	0	2	0%
Port	0	2	0%
Misc.	0	3	0%
Total	178	575	31%

5.1.2 Fleet Size

Table 4-3 and Figure 4-1 illustrate the distribution of fleet sizes in the database. The average fleet size is 141 with vehicles and equipment combined. Most fleets (84%) have fewer than 100 vehicles and pieces of equipment in their fleets. 30% of fleets have 9 or fewer vehicles and pieces of equipment.

Table 4-4 provides the average fleet size for each fleet type in the database. Fleet size seems to mirror the "service territory" of each fleet with the state fleet being the largest and airports and school districts the smallest.

Finally, TIAX looked at average fleet age by fleet size (Figure 4-2). Vehicle and equipment operated in smaller fleets seemed to be about 2 years older in average than vehicles in larger fleets. Vehicle and equipment model year is a relatively well reported field (94% record completeness), which increases the validity of this trend. The difference in average age could be due to higher turnover rates in larger fleets such as Caltrans fleet of over 9,000 vehicles.

Table 5-3. Fleet Size Distribution[a]

Fleet Size	Vehicles Only	Equipment Only	Vehicle and Equipment	All Fleets	Distribution of Fleets
0-4	12	2	8	22	12%
5-9	2	1	28	31	17%
10-29	3	0	44	47	26%
30-49	1	0	26	27	15%
50-99	1	0	24	25	14%
100-499	1	0	17	18	10%
500-999	0	0	5	5	3%
1,000-4,999	0	0	2	2	1%
5,000-9,999	0	0	1	1	1%
Total	20	3	155	178	

[a] These fleets were included in the vehicle and equipment category. Three responding fleets had neither vehicles nor equipment meeting the database requirements.

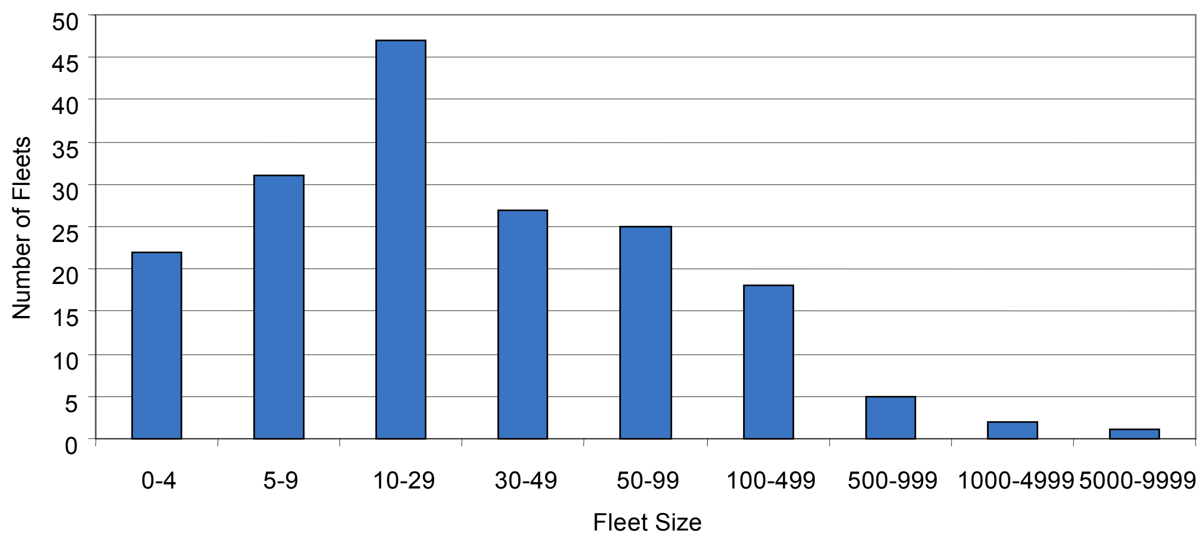

Figure 5-1. On-road Vehicles and Off-road Equipment Fleet Size Distribution

Table 5-4. Average Fleet Size by Fleet Type

Fleet Type	Number of Vehicles
State	2,642
Utility District	199
County	129
City	99
Transit	39
Water District	38
Irrigation District	22
University	15
Airport	4
School	1

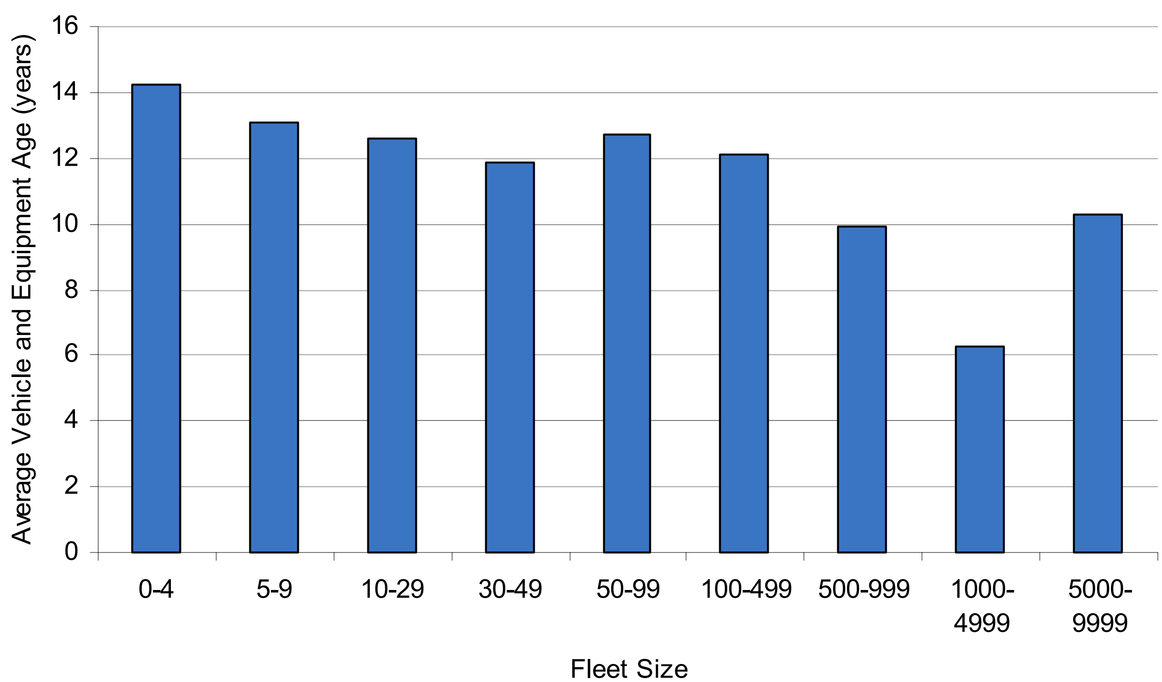

Figure 5-2. Average Fleet Age by Fleet Size

5.1.3 Vehicle and Equipment Acquisition

According to Table 4-5 most vehicles and equipment are purchased new. Very few fleets (6%) only purchase used vehicles and equipment and none only operate rented or leased vehicles and equipment. Table 4-6 shows that, for the fleets that reported their typical vehicle and equipment acquisition protocol, larger fleets tend to purchase new equipment. Table 4-7 presents the acquisition pattern by fleet type.

5.1.4 Geographic Distribution

The fleets in the public fleet database operate in 54 of California's 58 counties. The top 10 fleet locations are presented in Table 4-8. Half of the top 10 operation locations for these fleets are in Southern California. The operation county distribution from respondent fleets is similar to the distribution for all sent surveys presented in the last column of Table 4-8. Table 4-9 confirms that the database provides an accurate representation of the state's public fleet geographic distribution. Table 4-9 shows that the level of response by county averages about 45% for the top 10 counties. No California county seems to be significantly over represented in the database.

Table 5-5. Vehicle and Equipment Acquisition Patterns

Acquisition Type	Number of Fleets	Distribution of Fleets
Purchase New only	112	63%
Purchase New and/or Used	30	17%
Purchase Used only	10	6%
Purchase New, Used, Rent, and/or Lease	7	4%
Not Provided	*19*	*11%*

Table 5-6. Vehicle and Equipment Acquisition Patterns by Fleet Size

Acquisition Type	Average Fleet Size
Purchase New	98
Purchase Used	35
Purchase New,Used, Rent and/or Lease	37
Not Provided	*657*

Table 5-7. Acquisition Type by Fleet Type (Percentage of Fleets)

Type	Purchase New Only	Purchase Used Only	Purchase New, Used, Rent and/or Lease	Not Provided
City	71%	3%	13%	13%
County	57%	3%	27%	13%
Water District	58%	10%	29%	3%
Irrigation District	25%	17%	58%	0%
Transit	90%	0%	0%	10%
University	50%	0%	50%	0%
Utility District	67%	0%	0%	33%
State	50%	25%	0%	25%
Airport	0%	100%	0%	0%
School	100%	0%	0%	0%
Total	63%	6%	21%	11%

Table 5-8. Top 10 Fleet Operation Location

County	Number of Respondent Fleets	Distribution of Respondent Fleet	Distribution of Sent Survey
Riverside	19	9%	8%
Los Angeles	16	7%	8%
San Bernardino	15	7%	6%
San Diego	13	6%	5%
Orange	11	5%	5%
Kern	10	5%	4%
Shasta	7	3%	3%
Alameda	6	3%	3%
Monterey	6	3%	2%
Sacramento	6	3%	3%

Table 5-9. Response Rate by Geographic Area

County	Number of Received Surveys	Number of Sent Surveys	Response Rate
Riverside	19	42	45%
Los Angeles	17	45	38%
San Bernardino	15	33	45%
San Diego	13	28	46%
Orange	11	26	42%
Kern	10	22	45%
Shasta	8	15	53%
Alameda	6	16	38%
Monterey	6	12	50%
Sacramento	6	14	43%

5.1.5 Fueling Location

A majority of fleets use their own fueling stations, as shown in Table 4-10. A small number of fleets (8%) use more than one fueling location. Fleets that listed "Other" as a fueling location typically identified card lock facilities and fuel distributor terminals as their alternative fueling location.

Table 5-10. Fueling Facility Location

Fueling Facility	Number of Fleets	Distribution of Fleets
Fleet-Owned Station	101	57%
Retail/Truck Stop	34	19%
Other	26	15%
Job-Site Fueling	25	14%
Not Reported	21	12%

5.1.6 Ultra Low Sulfur Diesel (ULSD) Access

About 30% of the fleets in the database claimed to have access to ULSD. These fleets are mostly located in Southern California and the San Francisco Bay Area as shown in Table 4-11. However, the ULSD field was among the least complete in the Fleet Information Form with only 81% of flees reporting access to the fuel. Many of the surveys with no response were marked by a question mark sign indicating the survey respondent was not familiar with Ultra Low Sulfur Diesel.

Table 5-11. ULSD Access Location

Location of Fleets with Access to ULSD	Number of Fleets	Distribution of Fleets with ULSD Access
Southern California	27	51%
San Francisco Bay Area	12	23%
Sacramento Area	7	13%
Central Valley	5	9%
Northern California	2	4%

5.1.7 Incentive Choices

When asked about incentives for reducing emissions, most fleets responded that government grants would be necessary for the fleet to implement low emission retrofits. Table 4-12 compiles the results for this question. Fleets were encouraged to enter additional incentive choices to those provided in the survey. Among the other suggested incentives were quality OEM retrofits and government mandates.

Table 5-12. Preferred Incentive Type

Incentive Type	Percentage of Fleets
Government Grants	67%
Green Image	10%
Tax Incentives	4%
Other	3%

5.2 Vehicle and Equipment Characteristics

The data collected from the Vehicle and Equipment Form was analyzed to identify the main characteristics of on-road vehicle and off-road equipment operated by public fleets. The following sections provide summary tables presenting the vehicle/equipment and engine data collected.

5.2.1 Vehicle and Equipment Type

Table 4-13 and 4-14 present the ten most common vehicle and equipment types in the database. Most of these vehicles and equipment are construction and road maintenance-related. In the vehicle population there is a mixture of multi-purpose vehicles, such as pickup trucks and vans, and specialized vehicles like plow trucks and sweepers. Off-road equipment is by nature more specialized to a specific task. However, some pieces of equipment also have multiple functions. For example, generators can be used to provide power at a construction site or back-up power in a fleet facility. Figures 4-3 through 4-4 are examples of some of the most common vehicles and equipment reported in the survey.

Table 5-13. Top 10 Vehicle Type Summary

Vehicle Type	Number of Vehicles	Distribution of Reported Vehicle Types
Dump Truck	2,377	13%
Utility Truck	2,346	12%
Pickup Truck	2,256	12%
Van	1,224	6%
Cargo Truck	1,028	5%
Service Truck	950	5%
Plow Truck	809	4%
Sweeper	805	4%
Other Truck	740	4%
Plow & Spreader Truck	649	3%

Table 5-14. Top 10 Equipment Type Summary

Equipment Category	Number of Equipment	Distribution of Reported Equipment Types
Loader	1,035	19%
Grader	676	12%
Forklift	518	9%
Backhoe Loader	467	8%
Road Sign	342	6%
Mower	309	6%
Track-Type Tractor	247	4%
Generator	191	3%
Tractor	183	3%
Roller	169	3%

Source: Photograph from www.dot.ca.gov

Figure 5-3.   Caltrans Dump Truck

Source: Photograph from www.dot.ca.gov

Figure 5-4.   Caltrans Plow and Spreader Truck

Source: Photograph from www.machinerytrader.com

Figure 5-5. Loader

Source: Photograph from www.machinerytrader.com

Figure 5-6. Grader

5.2.2 Application Type

Among the surveys specifying a vehicle or equipment application, construction and maintenance are the most common for both vehicles and equipment, as seen in Tables 4-15 and 4-16. These responses are consistent with the vehicle and equipment types in the database. Unfortunately, the majority of survey responses (64%) do not specify a vehicle or equipment application. An application was not specified for 64% of the vehicle and equipment records.

Table 5-15. Vehicle Application Summary

Vehicle Application	Number of Vehicles	Distribution of Reported Vehicle Applications
Construction	1,465	51%
Maintenance (road, sewer, trees, snow)	984	34%
Delivery	180	6%
Industrial	82	3%
Transportation (staff)	59	2%
Animal Collection	57	2%
Agriculture	35	1%
Landscape	19	1%
Emergency	6	<1%
Commercial	5	<1%
Not Provided	*15,986*	

Table 5-16. Equipment Application Summary

Vehicle Application	Number of Equipment	Distribution of Reported Equipment Applications
Construction	2,396	56%
Maintenance (road, snow, landfill)	838	20%
Industrial	450	11%
Landscape	351	8%
Agriculture	148	3%
Commercial	50	1%
Emergency	40	1%
Delivery	11	<1%
Not Provided	*1,276*	

5.2.3 Fuel Type Distribution

The majority of vehicles and equipment in the database are diesel fueled. This is not surprising since the survey targeted vehicles and equipment in the heavy-duty sector, which predominately uses diesel fuel.

Among on-road vehicles, gasoline is also a prominent fuel. As shown in Table 4-17, over 40% of the vehicles are gasoline. While compressed natural gas (CNG) vehicles do exist in the fleet, they represent only one percent of the total vehicles. Other alternatives, such as propane, electric, and dual fuel (either diesel and CNG or gasoline and CNG), represent very small portions of less than one percent.

Alternative fuels are represented in greater proportion in the survey of off-road equipment. Although diesel dominates the sector, propane and electric equipment do represent approximately four percent of the fleet, as indicated in Table 4-18.

Table 5-17. Vehicle Fuel Type Distribution

Fuel Type	Number of Vehicles	Distribution of Reported Fuel Type
Diesel	10,184	54%
Gasoline	8,104	43%
CNG	138	1%
Propane	24	0.1%
Dual Fuel (NG+ Diesel or Gas)	24	0.1%
Electric	2	< 0.1%
Other	4	< 0.1%
Not Provided	*393*	

Table 5-18. Equipment Fuel Type Distribution

Fuel Type	Number of Equipment	Distribution of Reported Fuel Type
Diesel	4,825	88%
Gasoline	383	7%
Propane	189	3%
Electric	76	1%
Not Provided/Other	*87*	

5.2.4 Vehicle and Equipment Make

In nearly all surveys, respondents provided information about the make of their vehicles and equipment. As shown in Table 4-19, slightly more than 50% of the vehicles are manufactured by either GMC or Ford. These vehicles include both light-duty and light and medium heavy-duty vehicles. International/Navistar and Freightliner are the main manufacturers of heavy heavy-duty vehicles included in the database.

Equipment manufacturers are provided in Table 4-20. The three largest makes of off-road equipment are Caterpillar, John Deere, and Case, accounting for approximately 40% of the inventory. These manufacturers provide a full range of equipment ranging from construction to portable to landscaping equipment.

Table 5-19. Most Common Vehicle Makes

Vehicle Make	Number of Vehicles	Distribution of Reported Vehicle Make
Ford	4,879	26%
GMC	4,547	25%
International	2,746	13%
Dodge	1,834	10%
Chevrolet	1,689	9%
Navistar	466	3%
Freightliner	391	2%
Athey-Mobil	257	1%
Kenworth	221	1%
Peterbilt	158	1%
Not Provided	*439*	

Table 5-20. Most Common Equipment Makes

Vehicle Make	Number of Equipment	Distribution of Reported Equipment Make
Caterpillar	898	16%
John Deere	755	14%
Case	587	11%
Dresser	242	4%
Eng. Safety Dev.	218	4%
Ford	210	4%
Ingersoll-Rand	200	4%
Clark	119	2%
Champion	106	2%
Fiat-Alllis	91	2%
Not Provided	*111*	

5.2.5 Engine Make

Similar to vehicle and equipment makes, most survey respondents specified the manufacturer of the engines. However, many did not provide information about engine models.

Among fleets that specified engine make, more than 60% of the vehicles are made by Ford, GMC, or International. Table 4-21 shows the number of engines of these and other manufacturers that represent one percent or more of the database.

Vehicles with engine model specified comprise only one half of the vehicles in the database. Among specified engine models, the most common engine models are made by International. Approximately 16% of the engines are DT466 or DTA466 models. Five other manufacturers are represented in the models that comprise 30% of specified engines. Nevertheless, 21 different engine manufacturers were reported by survey respondents.

Although an effort was made to derive engine model data from vehicle model and vehicle model year, it was not possible to improve the low level of completeness for engine model information. This is mainly because several engine models are available with each vehicle model. It is, therefore, not possible to narrow down the engine model to one specific model knowing only the vehicle model and vehicle model year.

Table 5-21. **Most Common Vehicle Engine Makes**

Make	Number of Engines	Distribution of Reported Engine Make
Ford	4,879	26%
GMC	4,547	24%
International	2,746	15%
Dodge	1,834	10%
Chevrolet	1,689	9%
Navistar	466	2%
Freightliner	391	2%
Athey-Mobil	257	1%
Peterbilt	221	1%
Not Provided	*439*	

Table 5-22. **Most Common Vehicle Engine Models**

Make	Model	Number of Vehicles	Distribution of Reported Engine Models
International	DT466	1,009	12%
International	DTA466	393	4%
Caterpillar	3126	265	3%
Caterpillar	3116	250	3%
Cummins	N14	203	2%
GMC/Chevrolet[a]	350	149	2%
International	T444E	124	1%
Cummins	M11	114	1%
Ford	EFI	108	1%
Dodge	360	106	1%
Make and Model Not Provided		*9,698*	

[a] Model 350 was listed both as a GMC and Chevrolet model.

The results for equipment engines are also fairly incomplete due to lack of data received in the surveys. Although more than half of the population of equipment has an engine make specification, only 40% of the population has an engine make and a model specification.

For engine make, Caterpillar and John Deere dominate the equipment population — nearly 50% of the population with known engine make are made by these two manufacturers. Case, Cummins, and Ford also have significant representation in engine models, as shown in Table 4-23. In total, 105 different engine manufacturers are represented in the database.

The model distribution in Table 4-24 follows the make distribution above. However, there are a large number of different models listed by respondents such that any particular model has a fairly low number of engines. In addition, many model names are similar but slightly different. For example, in Table 4-24, a John Deere engine is referred to as 4045T, but this includes engines listed as 4045T and 4045 T. In developing the list of most common models, similar ones like these were assumed to be the same model, but model names with additional letters or numbers were not included as the same model.

Table 5-23. Most Common Equipment Engine Make

Make	Number of Engines	Distribution of Reported Makes
Caterpillar	859	29%
John Deere	578	19%
Case	302	10%
Cummins	248	8%
Ford	214	7%
Detroit Diesel	112	4%
Perkins	99	3%
Mitsubishi	53	2%
Deutz	45	2%
Nissan	31	1%
Not Provided	*2,553*	

Table 5-24. Off-road Engine Model Distribution

Make	Model	Number of Engines	Distribution of Reported Engine Models
Caterpillar	3306	160	7%
Caterpillar	3304	76	3%
Case	4390	76	3%
Caterpillar	3406	67	3%
John Deere	4045T	48	2%
Caterpillar	3126	41	2%
John Deere	4236	25	1%
John Deere	3179	20	1%
Model and Make Not Provided		*3,266*	

5.2.6 Gross Vehicle Weight Rating Distribution

TIAX assessed the distribution of vehicle GVWR using vehicle classes as defined by the Commercial Carrier Journal. The results are presented in Table 4-25. As GVWR is not commonly used to characterize off-road equipment and was generally under reported for equipment, TIAX did not include an assessment of equipment GVWR. The majority of vehicles in the database are less than 16,000 lbs. GVWR, with 39% less than 10,000 lbs. The greater percentage in the lowest weight category is likely due to the significant number of pickup trucks and large sport utility vehicles used by public agencies. The GVWR distribution is illustrated in Figure 4-7.

Table 5-25. Vehicle Gross Vehicle Weight Distribution

Vehicle Class	Vehicle Type Example	GVWR (lbs.)	Number of Vehicles	Distribution of Reported GVWR
Class 2	Van, Pickup Truck	8,500-10,000	6,160	39%
Class 3	City Delivery Truck, Large Pickup Truck	10,001-14,000	1,326	8%
Class 4	Large Walk-in Truck	14,001-16,000	1,444	9%
Class 5	Large Walk-in Truck	16,001-19,500	275	2%
Class 6	Single Axle Truck	19,501-26,000	1,549	10%
Class 7	Fuel & Lube Truck, Tow Truck	26,001-33,000	2,996	19%
Class 8	Refrigerated Truck, Cement Mixer	33,001 and greater	2,161	14%
Not Reported			*2,962*	

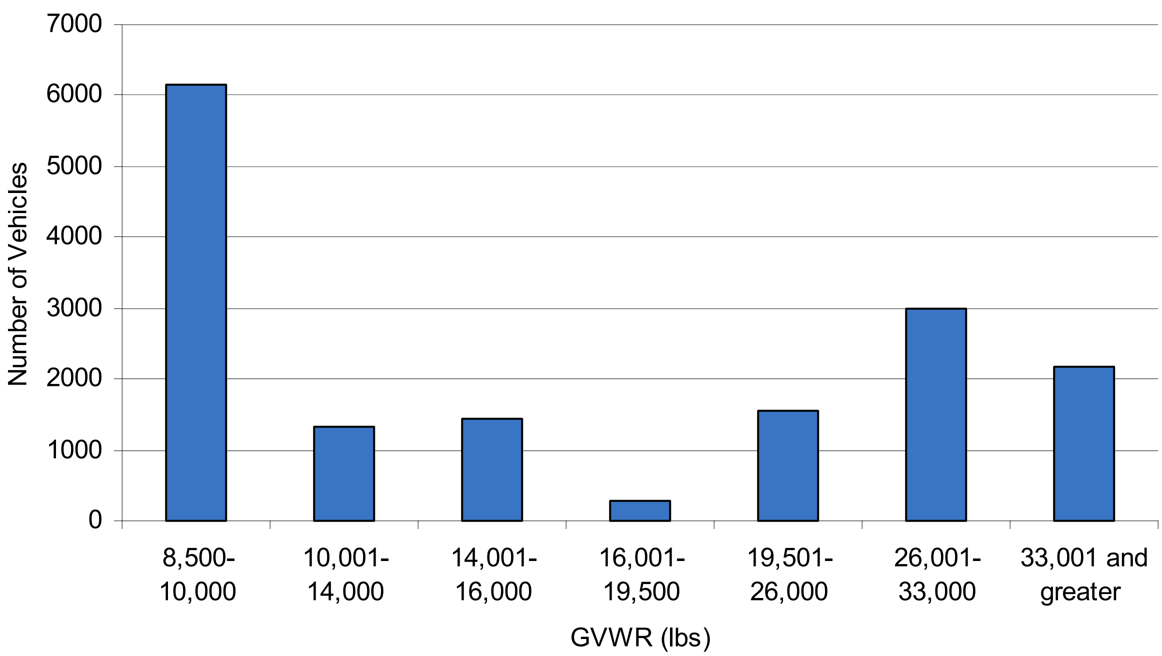

Figure 5-7. Vehicle Gross Vehicle Weight Distribution

In order to determine the link between GVWR and fuel type, TIAX estimated the average GVWR by fuel type. The results of the analysis are presented in Table 4-26. Gasoline and alternative fuel vehicles tend to be smaller, lower GVWR vehicles than diesel vehicles, which on average are between 26,001-33,000 lbs. GVWR.

Table 5-26. Average GVWR by Fuel Type

Fuel	Average GVWR Class
Gas/CNG, Bifuel	Class 2
Gasoline	Class 3
CNG	Class 4
Propane, Other Natural Gas	Class 6
Diesel	Class 7
Diesel/CNG	Class 8

Although it would be ideal to examine how GVWR relates to equipment or vehicle application, neither set of data is complete enough to do so. Nevertheless, it is likely that the larger vehicles represent the construction activities in which public agencies are involved.

5.2.7 Vehicle and Equipment Model Year

The survey of vehicle and equipment model year shows that vehicles have a shorter turnover rate than equipment. The average vehicle age is 9 years whereas the average equipment age is close to 14 years. About 64% of the vehicles for which model years are provided are 10 years old as shown in Figure 4-8. Fewer than 4% are older than twenty years. For equipment, however, Figure 4-9 shows a wider range in age. While there are still relatively few old pieces of equipment, only 43% of equipment with model year data available is less than ten years old. As the survey period ranged over 2 model years, 2002 and 2003, these model years are generally underreported.

TIAX also analyzed the distribution of the vehicle and equipment in the model year bins created by engine emission standards. Vehicle model year was used for this analysis because it is significantly more reported than engine model year. Engine emission standards are often an indicator of engine technology; newer engine tend to include more sophisticated emissions controls. The data in Table 4-27 shows that 42% of the diesel vehicles for which model year information was provided meet the lowest PM standard of 0.05 g/bhp-hr. Table 4-28 shows that over one third of the gasoline vehicle fleet for which model year data was available meet the latest NO_x standard.

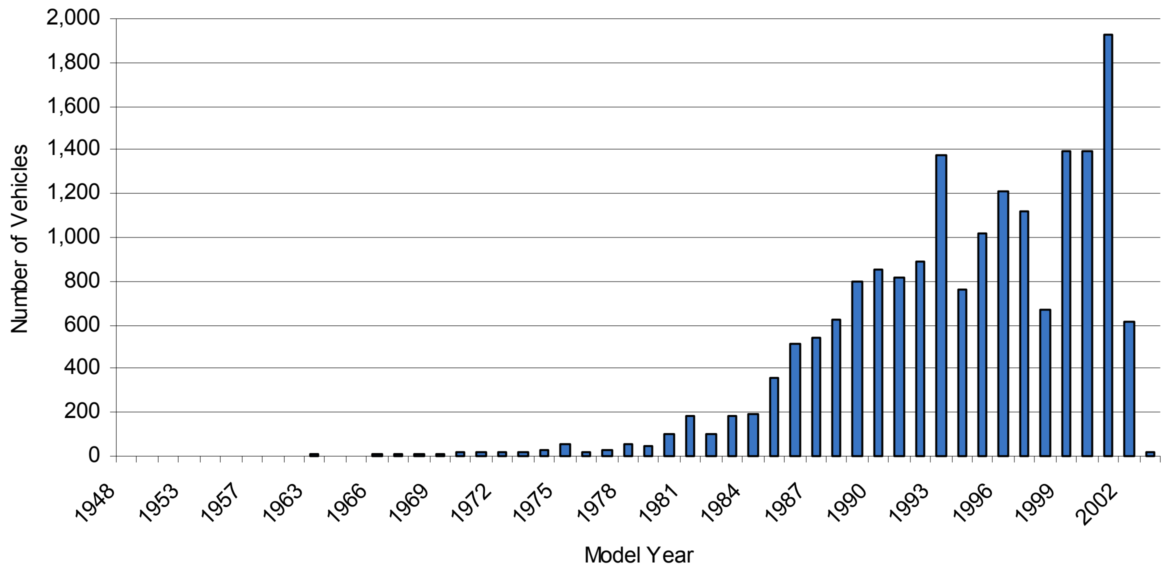

Figure 5-8. Vehicle Model Year Distribution

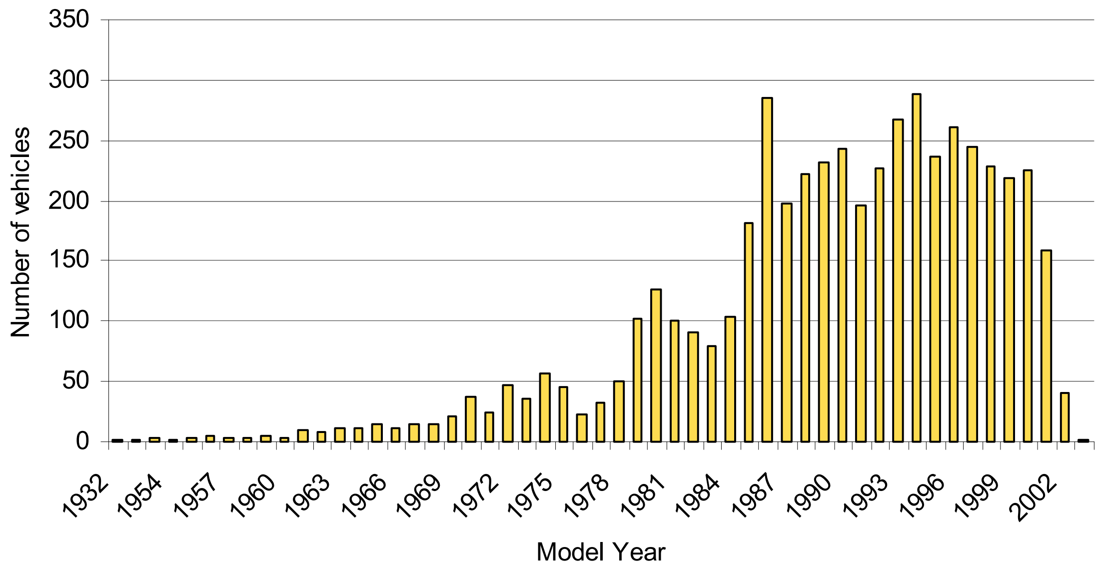

Figure 5-9. Equipment Model Year Distribution

Table 5-27. Diesel Vehicle Model Year Distribution In Emission Standard Model Year Bins

Model Year	NO_x Standard (g/bhp-hr)	PM Standard (g/bhp-hr)	Number of Vehicles	Distribution of Reported Vehicles
Pre 1977	10	N/A	108	1%
1977-1979	7.5	N/A	71	1%
1980-1983	6	N/A	331	3%
1984-1986	4.5	N/A	565	6%
1987-1990	6	0.6	1,592	16%
1991-1993	5	0.25	1,953	20%
1994-1995	5	0.1	1,008	10%
1996-1997	5	0.05	1,221	12%
1998-2002	4	0.05	2,953	30%
2003	2.5 (NO_x+NMHC)	0.05	18	0%
Model Year Not Provided			*364*	

Table 5-28. Gasoline Vehicle Model Year Distribution In Emission Standard Model Year Bins

Model Year	NO_x Standard (g/bhp-hr)	Number of Vehicles	Distribution of Reported Vehicles
pre-1987	N/A	843	11%
1987	10.6	228	3%
1988-1990	6	926	12%
1991-1997	5	2,835	37%
1998-2003	4	2,835	37%
Model Year Not Provided		*437*	

Off-road equipment emission standards vary not only by model year but also by engine horsepower and displacement. Tables 4-29 and 4-30 provide the diesel and spark-ingited (gasoline and propane) emission standards. Off-road engines were first controlled in the late 1990's. Tables 4-31 and 4-32 provide the database diesel and spark-ignited equipment population according to the emission rate bins for controlled and uncontrolled engines. Horsepower and displacement were not included to allow for a simplified table format.

Table 5-29. 1998 and Later Diesel Equipment Emission Standards

HP	Tier	Model Year	NO_x	HC	HC+ NO_x g/bhp-hr-hr	CO	PM
50 to <100	Tier 1	2000-2003	6.9	—	—	—	—
	Tier 2	2004-2007	—	—	5.6	3.7	0.30
	Tier 3	2008 and later	—	—	3.5	3.7	—
100 to <175	Tier 1	2000-2002	6.9	—	—	—	—
	Tier 2	2003-2006	—	—	4.9	3.7	0.22
	Tier 3	2007 and later	—	—	3.0	3.7	—
175 to <300	Tier 1	1996-2002	6.9	1.0	—	8.5	0.40
	Tier 2	2003-2005	—	—	4.9	2.6	0.15
	Tier 3	2006 and later	—	—	3.0	2.6	—
300 to <600	Tier 1	1996-2000	6.9	1.0	—	8.5	0.40
	Tier 2	2001-2005	—	—	4.8	2.6	0.15
	Tier 3	2006 and later	—	—	3.0	2.6	—
600 to <750	Tier 1	1996-2001	6.9	1.0	—	8.5	0.40
	Tier 2	2002-2005	—	—	4.8	2.6	0.15
	Tier 3	2006 and later	—	—	3.0	2.6	—
> 750	Tier 1	2000-2005	6.9	1.0	—	8.5	0.40
	Tier 2	2006 and later	—	—	4.8	2.6	0.15

Table 5-30. Spark-Ignited Equipment Emission Factors

Displacement	Model Year	Durability Period	HC + NO_x (g/bhp-hr)
≤ 1 liter	2002 and later	1,000 hours ir 2 years	9
> 1 Liter	2001- 2003	N/A	3
	2004-2006	3,500 hours or 5 years	3
	2007 and later	5,000 hours or 7 years	3

Table 5-31. Diesel Equipment Model Year Distribution In Emission Rate Model Year Bins

Model Year	Number of Equipment	Distribution of Reported Equipment
pre-1969	80	5%
1969	13	1%
1970-1971	30	2%
1972-1979	197	12%
1980-1984	150	9%
1985-1987	206	12%
1988-1995	493	29%
1996-1999	326	19%
2000-2003	190	11%
Model Year Not Provided		*3,140*

Table 5-32. Spark-Ignited Equipment Model Year Distribution In Emission Rate Model Year Bins

Model Year	Number of Equipment	Distribution of Reported Equipment
pre-1983	60	26%
1983	7	3%
1984-2000	152	66%
2001	10	4%
2002	0	0%
2003	0	0%
Model Year Not Provided		*345*

5.2.8 Engine Characteristics: Horsepower, Displacement

The survey collected data on engine horsepower and displacement. Approximately three-quarters of the vehicle fleet data contains horsepower information. Most of the vehicle engines for which horsepower data was provided are between 200 and 299 HP (see Table 4-33).

Table 5-33. Vehicle Horsepower Distribution

Horsepower	Number of Vehicles	Distribution of Reported Vehicles
≤ 99	100	1%
100-199	5,210	38%
200-299	6,488	47%
300-499	1899	14%
500-999	31	< 1%
Not Provided	*5,145*	

More than half of the equipment engines provided horsepower data. Most equipment engines tend to have smaller horsepower ratings than vehicles, with most engines under 199 HP (see Table 4-34). Since this study was only interested in equipment with greater than 50 HP, any data for lower horsepower was removed.

The displacement data is consistent with the trend observed in the horsepower distribution. Displacement distribution is presented in Tables 4-35 and 4-36. The vehicle engines tend to have, in average, greater displacement than the equipment engines. For example, most vehicle engines have a displacement between 4 and 8 liters, whereas most equipment engines have a displacement smaller or equal to 6 liters.

Table 5-34. Equipment Horsepower Distribution

Horsepower	Number of Equipment	Distribution of Reported Equipment
50-99	1,195	36%
100-199	1,750	53%
200-299	152	5%
300-499	188	6%
500-999	28	1%
1000 and greater	3	< 1%
Not Provided	*2,242*	

Table 5-35. Vehicle Engine Displacement Distribution

Displacement L	Number of Vehicles	Distribution of Reported Engines
>2, ≤ 4L	85	1%
>4, ≤ 6L	3,753	33%
>6, ≤ 8L	5,635	50%
>8, ≤ 10L	879	8%
>10, ≤ 12L	449	4%
>12, ≤ 14L	206	2%
>14, ≤ 16L	238	2%
Not Provided	*7,629*	

Table 5-36. Equipment Engine Displacement Distribution

Displacement L	Number of Equipment	Distribution of Reported Engines
≤ 2 L	38	2%
>2, ≤ 4L	756	38%
>4, ≤ 6L	500	25%
>6, ≤ 8L	292	15%
>8, ≤ 10L	68	3%
>10, ≤ 12L	167	8%
>12, ≤ 14L	21	1%
>14, ≤ 16L	84	4%
>16, ≤ 18L	10	1%
>18, ≤ 20L	22	1%
>20L	27	1%
Not. Provided	*3,573*	

5.2.9 Engine Control and Aspiration

Most vehicle engines for which data was available are mechanically controlled (60%), as indicated in Table 4-37. The disparity between mechanically and electronically controlled engines was most apparent in the diesel-fueled vehicles. Gasoline vehicles show a more comparable distribution between mechanical and electronic control. CNG, propane, and dual fuel engines tend to be electronically controlled. The data analysis is

Table 5-37. Vehicle Mechanical and Electronic Engine Distribution

Fuel Type	Mech.	Elect.	*Mech/Elect. Specification Not Provided*
Diesel	2,122	1,079	*6,983*
Gasoline	884	952	*6,268*
CNG	11	30	*97*
Propane	8	12	*4*
Dual Fuel (NG+ Diesel or Gas)	0	4	*20*
Other	2	1	*3*
Fuel Type Not Provided	37	1	*355*
Percentage of vehicles for which control data is available	60%	40%	—

based on approximately one-quarter of the fleet since control data were not provided for most vehicles. The low reporting level prevents any definite conclusion from being drawn from the engine control distribution.

For equipment engines, 93% of the engines are mechanically controlled as shown in Table 4-38. Again, half of the fleet data collected did not indicate type of control.

The difference between the portion of electronic engines in vehicles and equipment is consistent with TIAX's understanding that equipment engines are typically less sophisticated than vehicle engines.

Table 5-38. Equipment Mechanical and Electronic Engine Distribution

Fuel Type	Mech.	Elect.	*Mech./Elect. Specification Not Provided*
Diesel	2019	139	*2,667*
Gasoline	101	3	*278*
Propane	112	5	*72*
Electricity	2	14	*60*
Fuel Type Not Provided	2	1	*81*
Percentage of equipment for which aspiration data is available	93%	7%	—

Tables 4-39 and 4-40 indicate the findings on vehicle and equipment engine aspiration. Among vehicles, nearly three-quarters of the diesel and diesel based natural gas engines in the database where identified as turbocharged. Equipment data indicate slightly lower prevalence of turbocharged engines, but they still make up nearly two-thirds of the data.

Table 5-39. Vehicle Turbo Engine Distribution

Fuel Type	Turbo	*Not Turbo or Not Provided*
Diesel	7,565	*2,619*
CNG	17	*121*
Dual Fuel (NG+ Diesel or Gas)	0	*24*
Percentage	73%	*27%*

Table 5-40. Equipment Turbo Engine Distribution

Fuel Type	Turbo	*Not Turbo or Not Provided*
Diesel	3,074	*1,751*
Percentage	65%	*36%*

It is important to note that survey participants were asked to state whether the engines were turbocharged but were not asked if the engines were not turbocharged. As a result, no answer to the question could indicate an engine was not turbocharged, or it could indicate that the respondent did not know and therefore did not respond to the question.

5.2.10 Auxiliary Engines

The survey asked respondents to indicate vehicles and equipment that had auxiliary engines. Only 369 of nearly 19,000 vehicles (2%) and 37 of nearly 5,600 pieces of equipment (<1%) were identified with auxiliary engines.

Tables 4-41 and 4-42 show the types of vehicles and equipment that have auxiliary engines. The main vehicle type equipped with auxiliary engines is the sweeper, followed by the sewer truck. Among equipment, the blower and excavator have more auxiliary engines than other types of equipment.

Table 5-41. Vehicle Auxiliary Engine Distribution

Category	Number of Auxiliary Engines
Sweeper	150
Sewer Truck	74
Service Truck	19
Flatbed Truck	13
Utility Truck	13
Sprayer Truck	10
Water truck	10
Crane Truck	8
Tanker Truck	8
Other Truck	8
Other Categories	56
Total Auxiliary Engines	369

Table 5-42. Equipment Auxiliary Engine Distribution

Equipment Category	Number of Auxiliary Engines
Blower	14
Excavator	8
Grader	3
Off-road Truck	3
Crane	2
Other Construction Equipment	2
Track-Type Tractor	2
Backhoe Loader	1
Sweeper	1
Tractor	1
Total Auxiliary Engines	37

5.2.11 Mileage and Hours of Use Profile

Approximately one-third of the records in the Vehicle and Equipment Data Table has information on annual mileage or annual hours of use. This low record completeness does not allow for solid trends to be identified from the collected data. TIAX determined the distribution of annual vehicle mileage, which is presented in Table 4-43. Close to three-quarters of the vehicles for which mileage was provided accumulates less than 10,000 miles per year. A significant portion of these vehicles (38%) accumulates mileage under 5,000 miles each year. Table 4-44 shows the average annual mileage by vehicle category in the database. On average, vehicles for which data was provided accumulate about 8,000 miles per year. Figure 4-10 illustrates the annual vehicle mileage by model year. As expected, annual mileage decreases with vehicle age. The low annual mileage for model year 2002 and 2003 vehicles is perhaps due to fleets submitting mileage to date rather than expected mileage for their newest vehicles.

Table 4-45 compares the annual mileage by vehicle size to the EMFAC2002 statewide annual mileage. Although the database does not provide enough data points to make a conclusion, public fleet vehicles seem to accumulate fewer miles each year than the average statewide fleet. This is especially true for smaller, lower GVWR vehicles.

Table 4-46 provides equipment annual hours of use per equipment type and fuel. It also contains the ARB OFF-ROAD model annual hours of use by equipment type common to the database and the model. Once again the low number of data points affects the ability to conclusively compare the database and the OFF-ROAD data sets. As with the vehicles, public fleet equipment seems to be used fewer hours than the average equipment in the ARB model.

Table 5-43. Annual Vehicle Mileage Distribution

Annual Mileage	Number of Vehicles	Distribution of Reported Vehicles
0-5,000	2,264	38%
5,001-10,000	1,995	34%
10,001-15,000	975	17%
15,001-20,000	392	7%
20,000 and greater	260	4%
Not Provided	*12,987*	

Table 5-44. Vehicle Annual Mileage by Vehicle Category

Vehicle Category	Annual Mileage	Vehicle Category	Annual Mileage
Plow & Spreader Truck	20,030	Tanker Truck	6,124
Tow Truck	16,486	Aerial Lift Truck	5,902
Animal Control Vehicle	13,448	Lift Truck	5,802
SUV	12,071	Mower Truck	5,718
Wrecker	11,895	Flatbed Truck	5,296
Line Truck	11,886	Specialty Truck	5,234
Other Construction Vehicle	11,850	Water truck	4,652
Bus	11,435	Stakebed Truck	4,257
Bobtail Truck	10,836	Personnel Hoist Truck	3,905
Pickup Truck	10,680	Spreader Truck	3,590
Tractor Truck	10,328	Crane Truck	3,107
Service Truck	9,661	Bookmobile	3,060
Fence Repair Truck	9,558	Loader Truck	3,041
Utility Truck	8,705	Tree Trimmer	2,823
Crew Cab Truck	8,479	Plow Truck	2,357
Fuel & Lube Truck	8,240	Digger Derrick Truck	2,341
Van	8,229	Mixer Truck	1,865
Sewer Truck	7,985	Trailer	1,834
Cargo Van	7,654	Tack Truck	811
Straight Truck	7,518	Auger Truck	509
Paint Truck	7,496	Drill Truck	103
Patch Truck	7,387		
Sprayer Truck	7,137		
Survey Truck	7,125		
Other Truck	7,034		
Dump Truck	6,837		
Sweeper	6,685		
Chipper Truck	6,582		
Platform Truck	6,527	Fleet Average	7,965
Welder Truck	6,243		

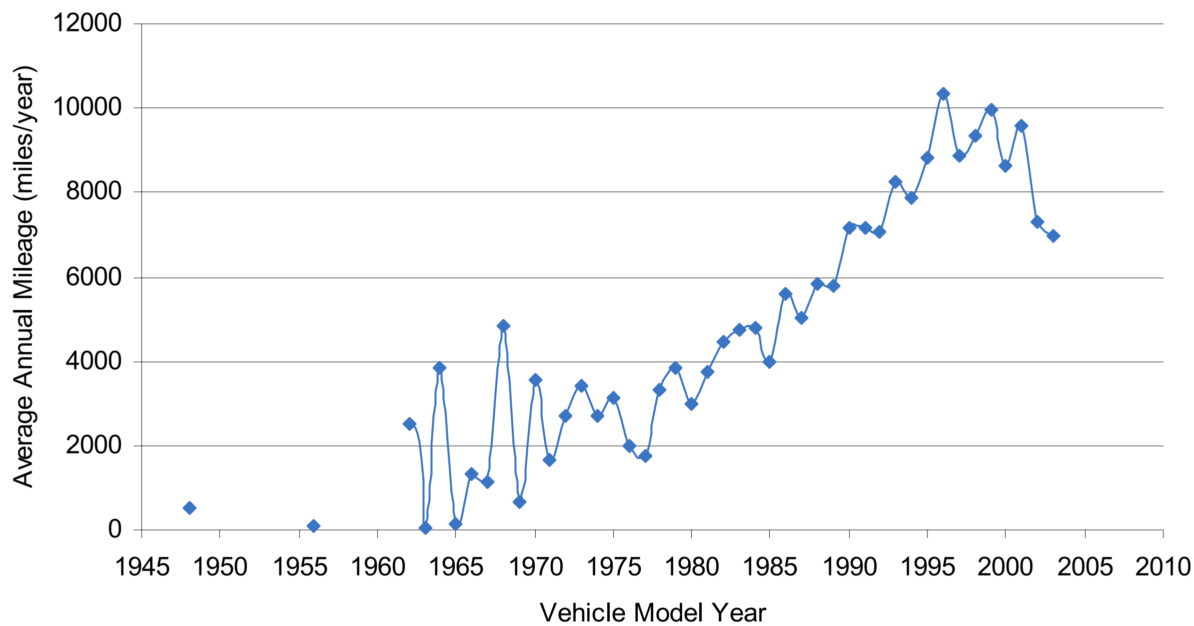

Figure 5-10. Annual Vehicle Mileage by Model Year

Table 5-45. Vehicle Annual Mileage Compared to EMFAC2002 Estimates

Vehicle Class (GVWR)	Public Fleet Average Annual Mileage	EMFAC2002 Average	Percent of EMFAC2002 Average

LHDT1 (8500-10,000)	8,870	20,377	44%
LHDT2 (10,001-14,000)	7,267	19,319	38%
MHDT (14,001-33,000)	6,603	18,778	35%
HHDT (33,001-60,000	8,020	48,964	16%
LHV (60,001+)	11,194	N/A	

Table 5-46. Annual Hours of Use for Off-road Equipment

Equipment Type	Survey Data			ARB OFF-ROAD Model	
	Diesel	Gas	Propane	Diesel	Gas/Propane
Air Compressor	114	89		815	484
Auger	135				
Backhoe Loader	405	5,554		1,135	870
Baler	90			95	68
Blower	215	141		400	
Broom	138				
Chipper	162	195		465	
Compactor	678	5		748	621
Compressor	47	5			
Crane	237			1,464	415
Drill Rig	200				
Excavator	1,665			1,162	
Forklift	146	130	400	1,800	1,800
Generator	92	15	32	338	115
Grader	415	28		965	
Grinder	51			622	
Lift		30		384	361
Loader	588	182	707	1,346	512
Mower	569			1,135	104
Off-road Truck	2,776			1,641	
Other Agricultural Equipment	222	100			
Other Commercial Equipment		30			
Other Construction Equipment	187	30			
Other Industrial Equipment	72				
Paver	122			828	
Pump	66	5		403	221
Roller	625	94		748	621
Scraper	471			1,090	
Skid Steer Loader	78				310
Skip Loader	280	60			
Snow Plow	148				
Spreader	162			622	175
Sweeper	92	30		1,220	516
Tow Tractor	319	237			

Track-Type Tractor	529			1,135	870
Tractor	432	20		1,135	870
Trailer		1			
Trencher	209			620	402
Trommel Screen	285				
Turf Tractor	320				733
Welder	191	227		643	
Wheel-Type Tractor	358	416		899	512
Fleet Average	420	293	385		

5.2.12 Fuel Use Profile

Fuel usage is one of the most underreported data sets. Table 4-47 and 4-48 summarize the average gallons of fuel used each year by vehicle and equipment type and by fuel type. Fleet averages are also reported.

Table 5-47. Vehicle Annual Fuel Use by Vehicle Category (gallons)

Vehicle Category	Fuel Type				
	Diesel	Gasoline	CNG	Propane	Dual Fuel
Aerial Lift Truck	911	875		871	
Animal Control Vehicle		1,491			
Auger Truck	87				
Bobtail Truck	1,104	791			
Bookmobile	1,190				
Bus	1,043	2,418			
Cargo Truck					
Cargo Van		930	444		
Chipper Truck	1,023	603			
Cone Truck	377				
Crane Truck	518	317		3,634	
Crew Cab Truck	894	1,160			
Digger Derrick Truck	372				
Drill Truck	690				
Dump Truck	1,142	1,431	603	1,016	
Fence Repair Truck					
Flatbed Truck	514	789		1,963	
Fuel & Lube Truck	1,557	325			
Lift Truck	494	680			
Line Truck					
Loader Truck	779				
Mixer Truck	558			633	
Other Construction Vehicle	2,186	284			

Vehicle Category	Diesel	Gas	CNG	Propane	Dual Fuel
Other Truck	778	917	1,010		741
Paint Truck	1,225	1,080			
Patch Truck	1,527				
Personnel Hoist Truck	728	375			
Pickup Truck	905	1,332	6		624
Platform Truck	1,034	129			

Table 4-47. Vehicle Annual Fuel Use by Vehicle Category (gallons) (concluded)

Vehicle Category	Fuel Type				
	Diesel	Gas	CNG	Propane	Dual Fuel
Plow & Spreader Truck	5,935				
Plow Truck	614				
Service Truck	1,240	1,563	886	145	
Sewer Truck	1,735	708			
Sign Truck	2,288	1,493			
Specialty Truck	492	1,060			
Sprayer Truck	705	452		2,964	
Spreader Truck	999	1,788			
Stakebed Truck	492	697	197	307	
Straight Truck	881	1,061			
Survey Truck	751	501			
SUV		1,098			
Sweeper	1,936	1,766	2,231		
Tack Truck	249				
Tanker Truck	699	332			
Tow Truck	1,957	489			
Tractor Truck	2,532	206			
Trailer	382		75		
Tree Trimmer	750	150			
Utility Truck	882	1,095		436	
Van	916	1,073	545	927	
Water truck	1,040	1,034			
Welder Truck	720	713			
Wrecker					
Fleet Average	1,185	1,144	786	1,038	648

Table 5-48. Equipment Annual Fuel Use by Equipment Category (gallons)

Equipment Category	Diesel	Gas	Propane
Air Compressor	184	39	
Auger	296		
Backhoe Loader	398		60
Baler	180		
Blower	1,623	1,080	
Broom	144	100	
Chipper	404	425	
Compactor	9,760	15	
Compressor	97		
Crane	264	38	
Drill Rig	24		
Excavator	1,045		
Forklift	76	205	950
Generator	511	477	207
Grader	12487	24	
Grinder	254		
Lift	1,543		
Loader	872	338	1,367
Mower	454		
Mower+Broom	758		
Off-road Truck	618		
Other Agricultural Equipment	288	234	
Other Commercial Equipment		6	
Other Construction Equipment	1,386	338	
Other Industrial Equipment	113		
Paver	315		
Pump	2,301	10	
Railroad Maintenance Equipment	1,133		
Roller	236	19	
Scraper	5,148		
Skid Steer Loader	83		
Skip Loader	341	193	
Snow Plow	458		
Spreader	587	7	
Sweeper	397	42	
Tow Tractor	282	158	
Track-Type Tractor	2,503	4	
Tractor	663	39	
Trailer		10	
Trencher	31		
Trommel Screen	426		
Turf Tractor	376		
Welder	101	17	
Wheel-Type Tractor	277	520	
Fleet Average	1,012	183	877

5.2.13 Vehicle and Equipment Rebuild Pattern

The study attempted to better understand rebuild patterns for both vehicles and equipment. Like many categories of requested information, the year of rebuild was provided for a small portion of the fleet. Respondents provided valid rebuild age information for only 132 vehicles and 110 pieces of equipment.

The average age of rebuild was determined by calculating the difference between the vehicle or equipment model year and year of engine rebuild. In a few cases, these were listed as the same year, or the year of rebuild was earlier than the model year. These data points were not used in determining the average age of rebuild.

The average vehicle engine rebuild age for various types of vehicle and equipment categories is shown in Tables 4-49 and 4-50. The average age of vehicles at rebuild is 12 years and the average equipment engine rebuild age is 15 years. Both of these ages are greater than the average vehicle and equipment ages.

Table 5-49. Rebuild Age Distribution by Vehicle Category

Vehicle Category	Average Age At Rebuild
Patch Truck	5
Bus	5
Paint Truck	7
Van	7
Lift Truck	8
Pickup Truck	8
Service Truck	9
Flatbed Truck	10
Aerial Lift Truck	10
CraneTruck	10
Straight Truck	10
Plow and Spreader Truck	11
Sewer Truck	11
Trailer	11
Tack Truck	12
Tractor Truck	14
Dump Truck	14
Other Construction Vehicle	16
Other Truck	16
Water Truck	16
Sprayer Truck	22
Sweeper	24

Table 5-50. Rebuild Age Distribution by Equipment Category

Equipment Type	Average Age At Rebuild (years)
Other Agricultural Equipment	7
Scraper	10
Skip Loader	12
Backhoe Loader	13
Off-road Truck	13
Track-Type Tractor	13
Tractor	13
Loader	15
Forklift	16
Grader	16
Excavator	18
Blower	21
Wheel-Type Tractor	23

5.3 Biases and Uncertainty

As with most surveys and survey data analyses, the methodologies selected to conduct the data collection and analysis can lead to biases and uncertainties in the results. In order to bound these issues, TIAX first examined whether the fleets included in the database were a representative subset of the fleets the surveys were sent to. In Sections 4.1.1 and 4.1.4, TIAX found that the database fleets accurately represented the geographic distribution and type of fleets the survey was originally sent to. We then looked at fleet size distribution. The only data available for the fleets we did not receive responses from is the DMV database diesel vehicle population estimates. To remain consistent we compared the DMV fleet size estimates for the fleets that responded to the survey to the fleet size distribution. The results of the comparison, presented in Table 4-51, show that the fleets in the database are also representative of the DMV estimated fleet size distribution.

Errors in the data contained in the database which affect the level of certainty in our analysis could have occurred during the survey completion by the fleet or during data entry into the database, or again during the data analysis itself. Because, for the most part, the surveys were completed by the fleets without the assistance of TIAX staff, it is not possible to assess to what extent completed surveys are an accurate representation of a fleet's characteristics. Some survey respondent errors were corrected during the data entry process. These include typographical errors, errors in correctly identifying on- and off-road equipment, and errors in providing total fleet size. Other potential survey

Table 5-51. Comparison of DMV Estimated Population Distribution

Fleet Size	Distribution of Survey Respondents	Distribution of Sent Surveys	Difference
0-4	55%	57%	1%
5-9	17%	17%	0%
10-29	10%	17%	7%
30-49	6%	5%	-1%
50-99	6%	3%	-4%
100-499	5%	2%	-2%
500-999	1%	0%	-1%
1,000-4,999	0%	0%	0%
5,000-9,999	0%	0%	0%

respondent errors such as underreporting of vehicle and equipment fleet could not be identified by TIAX staff.

During data entry, a verification procedure was implemented to ensure that no errors were introduced in the database. TIAX assumed that data obtained and entered electronically had a much lower potential of data entry error. To reduce the uncertainty linked to data entry, TIAX contacted all fleets that had provided hardcopy surveys that were obviously prepared using word processing or spreadsheet software and requested electronic copies of their submittals. Sixty-seven of the 178 surveys processed were received electronically. Other procedures were established to reduce data entry errors as described in Section 3.3. For example, data that could not be clearly read by two or more staff was not included. In some instances data entry staff judgement was necessary to complete specific fields. This is the case of the check box marking the equipment usage data units. Although most surveys indicated whether annual use was in miles or hours, because there was no assigned location for this information in the survey form, many fleets did not provide units for their annual vehicle and equipment use. In those cases, the units were deduced using a combination of vehicle/equipment type (off-road equipment is typically outfitted with an hourmeter) and data format (annual hours are typically much smaller number than annual mileage).

In the final data analysis, the main uncertainties relate to conclusions based on underreported data. The most uncertain conclusions in this analysis are those related to annual fuel use, annual mileage, and engine characteristics. Inasmuch as the fleets are representative of California public fleets operating in California, which was demonstrated above, the conclusions drawn on all other fleet and vehicle/equipment characteristics carry a high level of certainty.

6. Retrofit Potential

6.1 Retrofit Vehicle Profile

Recent verification of diesel particulate filters may enable some on-road vehicles to be retrofitted for lower emissions. Below are explanations of the types of reductions and the eligible devices and engines verified by ARB.[2] Table 5-1 provides a summary.

- Level 3 – 85% or greater reduction in particulate matter: ARB has verified Englehard DPX and Johnson Matthey CRT diesel particulate filters for use with most 1994-2002 MY diesel engines in on-road applications.
  - Conditions for the engines are: on-road, four stroke, certified at PM level of at most 0.1 g/bhp-hr, turbocharged.

- Clean Air Partners diesel particulate filter (DPF) is also applicable to some natural gas/diesel bi-fuel engines.

- Level 3 – 85% or greater PM reduction with 25% NO_x reduction: ARB has verified the Cleaire Flash and Catch™ systems for use with Cummins M11 1994-1998 MY diesel engines.
  - Conditions for the engines are: on-road, four stroke, certified at PM level of at most 0.1 g/bhp-hr, turbocharged.
  - The verification applies only to trucks with predominantly long haul applications and they must operate using fuel with sulfur content of no more than 15 ppm by weight (ultra low sulfur diesel).

- Level 1 – 25% or greater reduction in particulate matter: Cleaire Flash and Match oxidation catalyst based systems is verified for used with Cummins M11 1994-1998 MY engines.
  - Conditions for engines are: on-road, four stroke, certified at PM level of at most 0.1 g/bhp-hr, turbocharged.
  - Only Cummins M11 engines for steady state long haul applications and must operate using CARB #2 diesel fuel or ultra low sulfur diesel fuel.

- Level 1 – 25% or greater reduction in particulate matter: three Donaldson DCM Diesel Oxydation Catalysts and filtration systems. Eligible vehicles are either MY 1991-2002 or MY 1994-2002, depending on the system.
  - Conditions for engine are: on-road, four stroke, certified at PM level of 0.1g/bhp-hr or 0.25 g/bhp-hr, tubocharged. The 6000 series catalyst formulation system can be used on California diesel fuel while the 6100 series catalyst formulation system requires 15 ppm or lower sulfur content fuel.

[2] Eligible devices and engines are based on latest information available on the ARB web site: http://www.arb.ca.gov/diesel/verifieddevices/verdev.htm

Table 6-1. Summary of Engine Requirements for PM Retrofit Devices

Type of Reduction	On-road	Model Year	Four-stroke	Certified PM level of 0.1 g/bhp-hr	Certified PM level of 0.25 g/bhp-hr	Turbo-charged	Long Haul Truck	Fuel	Manufacturer
Level 3, PM reduction	✓	1994-2002	✓	✓		✓		Diesel or natural gas/diesel	Caterpillar, Cummins, Detroit Diesel, Mack, International, Volvo, Power System Associates (for bi-fuel)
Level 3, PM and NO_x reductions	✓	1994-1998	✓	✓		✓	✓	Ultra low sulfur fuel	Cummins M11 only
Level 1, PM reduction	✓	1994-1998	✓	✓		✓	✓	CARB #2 or ultra low sulfur diesel	Cummins M11 only
	✓	1991-2002 or 1994-2002	✓	✓	✓	✓		CA Diesel and/or ultra low sulfur diesel	15 manufacturers

6.2 Public Fleet Retrofit Potential

There may exist some potential to retrofit public fleets based on the information gathered in the survey. The extent of the retrofit potential is only tentatively known because survey respondents provided information of varying completeness. They provided none, some, or all of the information necessary to determine whether the vehicles fit the profile for retrofit. Table 5-2 describes the various combinations of data gathered from the survey. All engines in the table are diesel-fueled. There is also one engine that may fit the profile for the Level 3 bi-fuel retrofit.

There are 1,784 vehicles that fit the model year specification, are one of the approved manufacturers, and are turbocharged. These are the most likely fit for a retrofit at Level 3 (85% PM reduction). However, further duty-cycle information is necessary to fully verify the retrofit potential.

In addition to the vehicles possibly fitting the retrofit profile for Level 3 PM reduction, some of the Cummins M11 engines in the database may match the profile for Level 1 PM-only reduction or Level 3 PM and NO_x reduction devices currently certified. After eliminating those with missing turbo information and model years (see Table 5-3), only 38 vehicles remain. In the case of the Cleaire verified devices for the M11 engines, vehicles must operate similarly to long-haul trucks. Further information is needed about

Table 6-2. Level 3 (85% PM reduction) Retrofit Potential for Diesel Engines in Database

Profile	Number of Vehicles
No MY, correct manufacturer, turbo	6,717
Correct MY, no manufacturer, turbo	2,144
No MY, correct manufacturer, turbo not specified	2,076
Correct MY, correct manufacturer, turbo	**1,784**
Correct MY, no manufacturer, turbo not specified	120
Correct MY, correct manufacturer, turbo not specified	86

Table 6-3. Level 3 (PM and NO_x) or Level 1 Potential of Cummins M11 engines in database

Profile	Number of Vehicles
M11 Engines	135
M11 Engines, no MY, turbo	63
M11 Engines, correct MY	38
M11 Engines, correct MY, turbo	**38**

these vehicles to determine their actual potential for retrofit. The concern is that the duty cycle of public fleet vehicles may not fit the long-haul truck requirements.

Level 1 PM reduction using Donaldson systems has also been verified. Unlike the Cleaire devices for Cummins M11 engines, the Donaldson systems are applicable to many manufacturers and engine models. The diesel oxydation catalyst (DOC) mufflers and closed crankcase filtration systems are available for model years 1991-1993 and 1994-2002. As described in Section 5.1, particular fuel types are required for different DOC systems.

1,548 vehicles match the DOC's required model series and model year for MY 1991-2002 engines. The actual number of vehicles may be higher but it cannot be calculated due to lack of model or model year data for many of the entries. Table 5-4 indicates the number of turbocharged vehicles that could be eligible if further inspection shows that the model or model year match the retrofit requirements. The retrofit potential will also increase if some engines are turbocharged but were not specified as such in the survey. The potential for retrofitting the public fleet vehicles also depends on their duty cycles. The ARB does not state in its Donaldson verification documents whether the vehicles must operate at steady-state.

Table 6-4. Level 1 (25% PM reduction) Retrofit Potential using Donaldson Devices for MY 1991-2002 Diesel Turbocharged Engines

Applicability	Manufacturer	Number of Vehicles
Model and Model Year Correct	International	944
	Caterpillar	321
	Cummins	278
	DDC	5
	Subtotal	*1548*
Model Correct but Model Year Unknown	Caterpillar	160
	Cummins	122
	International	107
	DDC	20
	Volvo	14
	Subtotal	*423*
Model Year Correct but Model Unknown	Cummins	70
	International	23
	Caterpillar	28
	Subtotal	*121*
Model Year Correct[a]	International	230
	General Motors	51
	Ford	55
	DDC	13
	Caterpillar	9
	Isuzu	9
	Volvo	1
	Subtotal	*368*

[a] ARB does not designate an engine series for this manufacturer during the model years analyzed so it is unknown if the models in the database are appropriate for the retrofit. Vehicles with the appropriate model year and manufacturer are included in these values.

7. Conclusion

From February 2002 to February 2003, TIAX LLC conducted, on behalf of ARB, a survey of California's public fleets operating heavy-duty vehicles and large off-road equipment. The survey requested data on the fleets' operational characteristics and detailed information on their vehicle and equipment inventories. The collected data were compiled in a database with a record for each of the 178 fleets and 24,433 vehicles and pieces of equipment. Analysis of the data allowed us to draw several conclusions, which are presented below.

Most public fleets are involved in construction and infrastructure maintenance-related activities. The average fleet size is 141 (vehicle and equipment combined) with one-third of the fleets having fewer than 9 vehicles and/or pieces of equipment.

Public fleets typically purchase new vehicles and equipment. The average vehicle age is 9 years while the average equipment age is 13 years. Rebuild data were poorly reported. From the data gathered, the average vehicle age at rebuild is 12 years and the average equipment age at rebuild is 15 years.

Most of the vehicles and pieces of equipment reported are diesel fueled. One-third of the vehicles are gasoline fueled. The average gasoline on-road vehicle tends to be smaller (low GVWR) than the average diesel vehicle in the surveyed fleets. Alternative fuel vehicles and equipment account for about 2% of the total records. Fleet-owned fueling stations are the main fueling location for all fleets. Fewer than one-third of the fleets claim to have access to ULSD. The majority of the fleets with access to ULSD are located in Southern California.

GMC and Ford vehicles dominate the vehicle population. Caterpillar, John Deere, and Case are the most common equipment make. Engine makes follow the same distribution as vehicle makes. Vehicles tend to have larger (horsepower, displacement) and more sophisticated (control) engines than off-road equipment. Fewer than one-third of the diesel engines in the database are identified as turbocharged. Auxiliary engines were reported mainly in sweepers.

In general, both the vehicle annual mileage and the equipment annual hours of use are respectively lower than EMFAC2002 and OFF-ROAD estimates. However, these fields are among the most underreported and these trends are not conclusive.

Less than 10% of the vehicle engines in the database match the engine profile for Level 3 PM reduction retrofits. Approximately 1,500 vehicles are eligible for the currently available Level 1 PM, Level 3 PM or Level3 PM+ NO_x retrofit. As public fleet vehicles will most likely not have duty cycles similar to long haul trucks, which is one of the verification requirements for several of the currently available devices, duty-cycle restrictions will limit the number of vehicles that can be retrofitted with currently available devices.

In order to further assess the retrofit potential of the vehicles in public fleets, it will be necessary to obtain more complete engine, exhaust system, and vehicle duty cycle information. TIAX recommends that the fleets selected to conduct a detailed engine information be representative of the range of fleet types and compositions established in this analysis. Table 6-1 provides potential fleet selection criteria.

Table 7-1. Potential Engine Study Selection Criteria

Criteria	Representative Selection	Percentage of Fleets Represented by Selection
Fleet Size	10-49, 100-499	51%
Fleet Location	Southern California, Sacramento Area	30%
Fleet Type	City, State	53%
Fleet Activity	Construction, Maintenance	80% (of vehicle and equipment population)

Appendix A. Fleet Mailing List

Appendix B. DMV Population Estimates

Appendix C. Survey Forms